FIG: I.

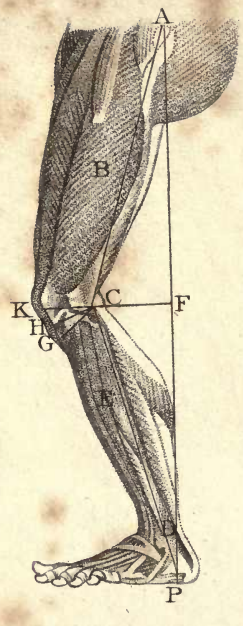
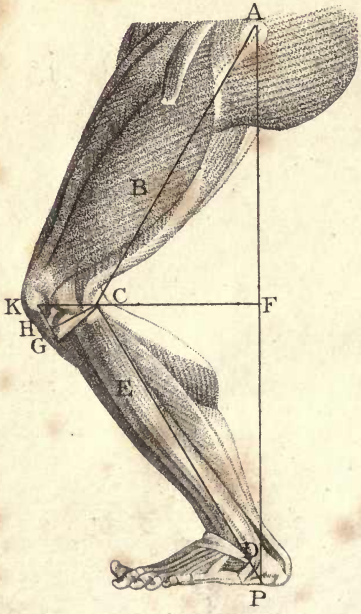


FIG: II.



INQUIRY

INTO THE COMPARATIVE FORCES

OF THE

EXTENSOR AND FLEXOR MUSCLES,

CONNECTED WITH THE JOINTS

OF

The Human Body.

BY

JULIUS JEFFREYS,

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TO

JOHN HENRY WISHART, Esq.

FELLOW OF THE ROYAL COLLEGE OF SURGEONS IN EDINBURGH,

&c. &c. &c.

AS A MARK OF RESPECTFUL ESTEEM,

AND A SENSE OF THE VALUABLE OPPORTUNITIES

ENJOYED UNDER HIS TUITION,

THE FOLLOWING INQUIRY

IS,

WITH PERMISSION, DEDICATED,

BY HIS GRATEFUL PUPIL, AND SINCERE FRIEND,

JULIUS JEFFREYS.

TO

JOHN HENRY WISHART, ESQ.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS IN EDINBURGH,

&c. &c. &c.

AS A MARK OF RESPECTFUL ESTEEM,

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An INQUIRY, &c.

Being convinced, that this inquiry is no less deserving of attention, from the practical uses to which it may be applied in Surgery, than it is interesting as a speculation in Physiology, and that it has not received the notice, which it merits, from those, who have made Myology a subject of investigation, I have been induced myself to attempt the prosecution of it.

The only author, as far as I am aware, who has treated of the present question, is Richerand, in his work upon Physiology. In this work, he has laid down as a theory, that the flexor muscles are in general stronger than the extensors. I have not been able to obtain any assistance from the work towards the prosecution of this inquiry,

inasmuch as the above theory appears to me untenable; being founded on principles, which are not correctly true, and deduced by reasoning in many respects defective. Hence, I may, perhaps, have some claim upon the indulgence of the reader, as all the following observations are original.

As Richerand's Physiology is a work of received authority, and as I am compelled, with respect to this part, so widely to dissent from him, I should, at all events, have had occasion to make frequent mention of his work. I will therefore, for the avoiding of repetition, deliver my opinions in the form of remarks upon it.

It will be necessary, however, that the following principles be kept continually in view, as being the foundation of the train of reasoning adopted in this Treatise.

First. By the extension of a limb must be understood the enlarging the angle of the joint, so

as to remove the extremities of the limb to a greater distance from each other: by the flexion of a limb, must be meant the diminishing the above angle, and bringing the extremities nearer to each other.*

Secondly. Many of our joints being only half-hinges—that is, capable of flexion in only one direction, complete extension, in the case of these joints, must necessarily be considered as an extreme position. It is as strictly the extreme position of the limb, on the one hand, as complete flexion is the extreme position, on the other.

Thirdly. The force inherent in a muscle is not in proportion to its length, but is dependent on its thickness, and is proportional to the number and strength of the fibres, in a given transverse section.

Fourthly. The power of a muscle in acting

* It may be thought unnecessary to *state* this principle; but it appeared to me proper, as I know some physiologists differ as to which is flexion and extension in certain joints, such as the ancle.

upon a limb must vary conjointly as the above-mentioned force, and the length of the arm of the lever upon which it acts.* Hence, if the same muscle act upon two joints, its power will be the greatest over that joint, upon which it acts, through the medium of a lever of the longest arm.

Fifthly. The contractile power of any muscle, when thrown into action, is greatest when the muscle is longest; but as the muscle shortens itself, so does this power decrease, until at last the muscle would have no power of shortening itself any further.

IN treating of motion, in his Elements of Physiology, Richerand observes†, "The extensor muscles are generally weaker than the flexors; hence the most natural position, that in which all the powers are naturally in equilibrio, that which our

* That is, when the angle is given with which it acts upon its lever. Where the angle differs, *it* must be taken into the consideration also.

† Elements of Physiology, translated by G. J. M. De Lys, M. D. p. 356.

limbs assume during sleep, when the will ceases to determine the vital influx to the parts under its control, that in which we can continue longest without fatigue, is a medium between flexion and extension, a real state of semiflexion."

Though this argument in support of the assertion may, at first sight, appear conclusive, it will not, I think, bear an attentive examination. The author evidently does not take into consideration the peculiar mechanism of many of our joints. Were our joints complete hinges—that is, did they bend with equal ease both ways; the leg, for instance, bending forwards, so that the toe might be brought to touch the groin, just as the heel may to touch the buttock; or, the thigh bending backwards, so that the posterior part of the knee might be carried to the scapula, just as the anterior part of the knee may to the clavicle; if, let it be repeated, our joints were hinges bending both ways, then certainly Richerand would be correct in supposing, that a superiority of power in the flexors, is the cause of the bent position of

the limbs in sleep; for if such were the structure of our joints, extension would be a mean position, between perfect flexion forwards, and perfect flexion backwards; and therefore, if the opponent muscles were equal in force, the limbs ought, during sleep, to assume a mean position, between the opposite kinds of flexion, i. e. ought to be extended; but, as our limbs are generally bent during sleep, it would certainly tend to prove, that the flexors were the more powerful muscles.

We must all know, however, that this is not the structure of our joints; and it is evident, that our limbs would be unstable, and, for many of their purposes useless, if it were so. Almost all the joints, and especially the larger ones, are only half hinges; that is, they can bend only in one direction; hence it is plain, that in them, extension is not a mean, but an extreme position; it is just as much an extreme position, on the one hand, as complete flexion is an extreme position on the other; and therefore, the mean position, which must be one equidistant from the extremes,

is that, in which the part of a limb below a joint, forms nearly a right angle, with the part above the joint. Were then the flexors of equal power with the extensors, this must be the position which our limbs would assume during sleep; or, in other words, we should sleep with our thighs and knees bent, as much as in sitting. Few persons sleep with their limbs so much bent; most people, I believe, sleep with their limbs forming very obtuse angles. If we inquire the reason of this, it will manifestly appear, that the extensors, instead of being weaker, as is Richerand's opinion, are more powerful than the flexors; and hence, necessarily extend the limb, when not under the command of the will, beyond the mean position between flexion and extension.

I am aware, however, that there is an objection, which might be brought against this argument—an objection, which, if it could be proved true, would be much in favour of Richerand's proposition. It is this: that, if we suppose, when a limb is extended, and at the same time inactive,

that the flexors and extensors are stretched equally tight between their insertions, were the extensors more powerful than the flexors, our limbs ought naturally to lie extended.

This objection would certainly be valid, if the flexors and extensors were stretched equally tense between their attachments. The two following considerations, however, will, I think, show that this is not the case; but that, when a limb is extended, and its muscles not excited to action, the length of the extensors bears a greater proportion to the distance between their attachments, than that of the flexors does, between the attachments of the latter; or, in other words, that the extensors, though not, perhaps, actually longer than the flexors, are virtually longer.

The first consideration is, that when any limb lies inactive in an extreme position, the muscles on one side are relaxed to the uttermost, while those on the other are stretched to the uttermost; but extension is an extreme position,

therefore, in this position the extensors are relaxed to the uttermost, while the flexors are in an equal degree stretched. Or, what is the same—when a limb is extended, the extensors are longer in proportion to the distance between their attachment than the flexors. The knee, and especially the hip, are remarkable proofs of this. When the knee is extended, the limb lying inactive, the patella and its ligament are quite loose, while the flexors are in the utmost degree stretched. Again; as to the hip-joint, we see that the thigh cannot be bent backwards as it can forwards. There is nothing in the articulation of the joint, which should so completely prevent this.* The reason is, that when the thigh is extended, the flexors of it are stretched, and do not admit of its being carried back without their laceration. Now, if the extensors were not longer, in proportion to the dis-

* The ligamentum teres, however powerful it may be in preventing too great rotation of the thigh outwards, and some kinds of dislocation, cannot be considered as the great preventative of its being carried backwards; its action in checking this movement must be very slight.

tance of their attachments than the flexors, the thigh, in like manner, could not be bent forwards without the extensors being lacerated; in fact, it would be immoveably extended.

The second thing to be considered is, the position of the limbs, when the muscles are created. In the fœtus, the spine is bent forwards, the knees touch the head, while the heels touch the buttock; the fists are closed, and the elbows bent;* and it is when the joints are in this state, that the muscles are created. The flexors, therefore, must be created virtually shorter than the extensors; for they are created, when their points of attachment are, in proportion, much nearer to each other than those of the extensors are.

* Lest this extreme state of flexion in all the limbs should be attributed by some to a superiority of strength in the flexors, which hence have drawn the limbs into that position; and lest it should be adduced as a proof of the greater power of the flexors in general, it may be observed, that the limbs are found in this state, at a period of gestation, when ossification has not been sufficiently completed to enable the bones to resist the action of muscles; in fact, it would be absurd, on all accounts, to imagine that they were formed in any other way.

It may, at first sight, strike the reader that so trivial a fact as the position of the limbs, when a person is at rest, or asleep, is not worthy of much reflection; but it seemed to me proper attentively to consider it, for two reasons. First, The somewhat bent position of our limbs in sleep, though in itself a matter of no importance, is, practically, well deserving of attention in surgery, for it nearly points out the natural and easy posture of limbs, which have suffered in various ways, especially from most kinds of fracture and dislocation. Secondly. Since Richerand has laid so much stress on this fact (and I think properly), but has drawn from it inferences very different from those, which, it appears to me, must be the result of due reflection, I have been induced to dwell for some time on it; and feel persuaded, that it tends to prove, that the extensors, instead of being weaker, are in general more powerful, than the flexors.

Let us now inquire into the nature of the joints individually; and I think we shall find, as

indeed might reasonably be expected, that the extensors, or flexors, are the more powerful, accordingly, as the former, or the latter, have to exert the most force.

In some joints—as those of the elbow, fingers, toes, &c., the flexors are certainly more powerful than the extensors; but in most of the large joints, I think it will be sufficiently evident, that the extensors are far the most powerful.

In supporting the doctrine he has laid down, Richerand continues: "If we examine the different parts of the body, the articulations of the limbs, and especially the knee, the knowledge of which is of the highest importance in understanding the theory of standing, it will be seen, that the flexor muscles exceed the extensors, in the number and length of their fleshy fibres." It is, however, scarcely just to adduce the knee-joint, in the manner in which he has made use of it. It is an instance, which might, perhaps, appear, at first sight, to support his doctrine, but which

requires considerably more examination, than he has allowed to it, before any decisive conclusion can be made from it. And the style, in which he introduces the various muscles, must, I think, tend to create deception. "If we compare," he says, "the biceps cruris, the semi-tendinosus, the semi-membranosus, the rectus-internus, the sartorius, the gemelli, the plantaris, and the popliteus, which all concur in the flexion of the leg; to the triceps cruris, and rectus, which extend the leg; we shall readily understand that the fibres of these last are much shorter,* and in smaller number."

Here I may remark, in the first place, that the long head of the Biceps, the Semitendinosus, and the Semimembranosus, which form a very large proportion of the muscles considered as flexors of the leg, arise from the tuber ischii; now the tuber ischii is at least three inches from the centre of motion of the hip-joint; and a line drawn

* What has length or shortness to do with strength?

from it to the centre of motion of the joint, when the thigh is somewhat bent, would form nearly a right angle with the thigh. Hence these muscles not only arise at the unusual distance of three inches from the centre of motion, but the whole of this distance is a lever;* a lever inferior to very few in the body, and which, of course, must give them a great power in extending the thigh.

Let us next consider what power these muscles possess in the flexion of the knee. In doing this we perceive that, owing to the peculiar structure of the posterior crucial ligament, the centre of motion of the knee is very near the back of the joint; and that on this account, and from their tendons being very much bound down by fascia, the above-mentioned muscles are not inserted more than an inch and three-fourths from the centre of motion of the joint; and, lastly, that they have not even the small lever of an inch and three-fourths, except when the leg is bent to a

* By the word lever, in this, and some following places, it will be evident, that we mean one arm of a lever, namely, that to which the power its applied.

right angle with the thigh; a position in which the flexors, having already contracted, must have less force for further contraction; and, when the leg is extended, it is plain they must act nearly in the same line with the thigh, and then can have but trifling power over the knee.

All these arguments being properly weighed, it will, I think, be admitted, that the long head of the Biceps, the Semitendinosus and the Semimembranosus ought to be considered chiefly as extensors of the thigh, their power over the knee is much inferior.

Very similar reasoning is applicable to the case of the Gastrocnemius, which being inserted into the os calcis far from the centre of motion of the ancle, and acting upon it with a lever of very great advantage, is scarcely to be named as a flexor of the knee, upon which it acts by a lever of little power.

Of the remaining flexors, even the Gracibis and

and Sartorius have to perform a double action, the former adduction of the thigh and flexion of the knee, the latter flexion both of the thigh and knee; and hence must execute either of these offices much less completely than if their action were single. As to the Popliteus, and Plantaris, their force must indeed be trifling. In fact the only muscle of any magnitude, whose sole action is flexion of the knee, is the short head of the Biceps.

Hence, an attentive examination would seem to show, that a far less force is exerted in the flexion of the knee, than at first sight would appear.

On the other hand, let us inquire into the force for extending the knee; and, I think, we shall find, that the muscles for this purpose are not only of immense magnitude, but that their sole action, with but a small deduction, is the extension of the knee.

The Rectus muscle is the only extensor which has a double action. As it arises from the ante-

rior inferior spine of the ilium, and from the upper edge of the acetabulum, it certainly must have some tendency to bend the thigh on the pelvis; but its power in this respect must be very small, since a great part of the muscle arises from the very edge of the acetabulum, nay actually adheres to the capsular ligament in its descent. Therefore, this muscle can only act as a flexor of the thigh, with a lever but little more than half the diameter of the head of the femur. The next muscle, the Vastus externus, arises entirely from the femur, viz. from the trochanter major, and greater part of the linea aspera; and forms nearly the whole of the large mass of flesh on the outer side of the thigh. The Vastus internus, on the inner side, arises from the trochanter minor, linea aspera, and whole of the interior of the thigh. These two muscles, named Vasti, from their great magnitude, send their fibres obliquely forwards and downwards, to join those of the Crureus, which occupies the anterior of the thigh, beneath the rectus. The two Vasti and the Crureus, being inserted into the patella, are solely

extensors of the leg. We may judge how powerful the action of these great muscles, together with that of the Rectus is, when we consider the following circumstances, which must add much to the power of the lever, by which they act. That the body of the femur is bent forwards; that the condyles project backwards; and that the posterior crucial ligament necessarily keeps the centre of motion of the knee near the back of the joint. Added to this, the action of the extensors is greatly facilitated by the presence of the patella, which also must aid the operation of these muscles, by removing their insertions further from the centre of motion, than they otherwise would be.

Lastly. A remarkable difference exists in the structure of the extensor and flexor muscles, which appears to me necessarily to give the former a great advantage, in point of strength, over the latter. Many of the flexor muscles of the knee arise from a few points, and are inserted at a few points, most of them into small tendons.

Hence it is plain that, when these muscles contract, the lower part of them acts upon the upper part, and depends upon it for support; and, therefore, any piece of one of these muscles, taken transversely, must have as much power as the whole muscle. On the other hand, all the extensors, except the Rectus, arise by numerous fibres the whole way down the femur, and are inserted at numerous points into their common tendon, into the patella, and into the aponeurosis covering the knee. The power of these muscles must be much superior from this circumstance alone. Each part of any of these muscles has an origin, and insertion independent of the rest of the muscle, and does not act upon the other part. So that the whole muscle, instead of only equalling a part of itself in strength*, as is the case with many of the flexors, is actually as much stronger, as it is larger than its part.

* I am well aware that this is not the case with all the flexors, especially the short head of the biceps and semi-membranosus; even these, however, are far inferior to the extensors in the advantageous structure described above.

From such an attentive examination, therefore, as I have attempted to carry on into the mechanism of the knee, and the action of the surrounding muscles, we are led, as I think, to an opposite conclusion to that, in support of which Richerand adduced this instance: namely, that the extensors, instead of being weaker, are more powerful than the flexors.

Let us next attend to the ancle-joint, and we shall find that it scarcely requires attentive examination, for of this joint the extensors are manifestly more powerful than the flexors

In inquiring into the action of the muscles moving the ancle-joint, we must remember that this joint bends in an opposite direction to those of the toes; and hence, that the long flexors of the toes are extensors of the ancle, and *vice versa*, that the long extensors of the toes are flexors of the ancle. The flexors of the ancle are, the Tibialis anticus, the Extensor proprius pollicis, the Extensor longus digitorum, and the Peroneus tertius.

The extensors of the ancle, which exactly correspond to these, are, the Tibialis posticus, the Flexor longus pollicis, the Flexor longus digitorum, and the Peroneus brevis. These extensors alone, are at least equal to the flexors; but far the most powerful extensors, the Gastrocnemius, and Soleus, the large mass of flesh forming the calf of the leg, and which act by a very powerful lever on the ancle, from their insertion into the os calcis, far from the centre of motion of the joint, together with the Peronneus longus, have no corresponding flexors. Therefore, the extensors of the ancle are plainly far more powerful than the flexors, for they are more numerous, most of them are much larger, and act by a lever very much superior in length.

The ancle joint, then, is another striking exception to Richerand's theory; and it militates directly against it.

An examination of the hip joint will, I am persuaded, shew that the extensors belonging to it are also the more powerful muscles.

The muscles generally enumerated as flexors of the thigh, are, the Sartorius, the Iliacus internus, the Psoas magnus, the Gluteus minimus, the Obturator externus, the Tensor vaginæ femoris, the Pectineus, the Gracilis, the Adductor longus and brevis, and the Rectus femoris. The three first of these, the Sartorius, Iliacus internus, and Psoas magnus, are the muscles on which the flexion of the thigh must chiefly depend. For the Sartorius, since it arises from the superior spine of the ilium, has the advantage of a powerful lever over the joint; and the other two are large muscles, which act directly as flexors of the thigh. The Tensor vaginæ femoris has the same advantage over the joint as the Sartorius, as far as the length of the arm of its lever is concerned; but is too small, to have much actual power. The Gluteus minimus, and Obturator

externus act upon arms of levers, which are too short to give them much effect as flexors. In fact, part of the former acts as an extensor, when the thigh is extended. The feeble action of the Rectus cruris, as a flexor, has been spoken of already. The remaining muscles, the Pectineus, Gracilis, Adductor longus, and brevis, can scarcely be reckoned as flexors of the thigh; for in the first place they act, even when the thigh is extended, upon levers of very little power; but, when the thigh is in a mean position between flexion and extension, they have no tendency whatsoever to bend it more; nay, when the thigh is completely bent, they actually become extensors! And in the next place, they arise from the os pubis so far interior to the acetabulum, as to act almost directly as adductors; hence, what small power, they would otherwise have as flexors, is nearly lost on this account alone; for even, when the thigh is extended, their action as flexors is extremely oblique.

On the other hand, the extensors of the thigh

are very powerful. First, the Gluteus maximus, a muscle of enormous size, and strong fibres, acts by a powerful lever upon the joint, as an extensor in most positions of the limb. The long head of the Biceps, the Semitendinosus and Semimembranosus, act as above observed by the means of powerful levers. The Adductor magnus must be ranked as a powerful extensor, for it is only, when the thigh is quite extended, that its anterior fibres do not act as extensors. Much the greater part of this large muscle acts as an extensor in any position of the limb, and has a superior advantage from its lever, to almost any of the flexors. To these may be added, the greater part of the Gluteus medius, which, though a large muscle, has not the most favourable lever as an extensor. Next to this in power is perhaps the Quadratus fermoris. The Pyriformis, Obturator internus, and Gemini are also enumerated as extensors; but their power in this way cannot be very great.

If then in order to render the examination of

the thigh as simple as possible, we leave out those muscles, which can have but little power either as extensors or flexors, I think we may oppose to each other the following muscles. As flexors, the Iliacus internus, Psoas magnus, Sartorius, and part of the Gluteus minimus; to the Gluteus maximus, the Adductor magnus, the long head of the Biceps, the Semitendinosus, the Semimembranosus, and part of the Gluteus medius, as extensors. Now it can hardly be doubted, that the latter are far the most powerful, especially as none of those flexors, except the Sartorius, have the advantage of a good lever, whereas, most of the extensors act by powerful levers. Hence, we also have, in the instance of the hip, a no less remarkable exception to the theory of Richerand, than in the former joints.

In attempting to judge of the comparative forces of the flexor, and extensor muscles of the vertebral column, though there are, actually, as many joints, as intervertebral spaces, it would be use-

less, and very tedious to treat of them singly; especially as many muscular fibres, which act upon vertebræ individually, are so connected, as to have induced anatomists to include several sets of them, under one name. It will, therefore, be most eligible to treat of the spine, as of two joints; namely of the neck, and of the back, and loins together.

As the flexion, or extension of the vertebral column, is performed by the united action of the muscles on the right and left of the spine; I shall treat of them in pairs; for the actions of the muscles on one side alone, would produce either of these effects very imperfectly.

In examining the muscles, which act upon that part of the vertebral column called the cervical, the first fact, which must present itself, is, that most of them are connected with the head. Hence it is plain, that they must induce a motion of the head on the atlas, at the same time, that they bend, or extend the cervical vertebræ. This

fact renders it quite unnecessary, to separate the inquiry into the moving powers of the head, from that, into those of the neck.

The Sterno-cleido-mastoidei are, in every respect, the principal flexors, for they are, in themselves, muscles of much strength, and have their insertion into the sternum and clavicle, so far anterior to the centres of motion of the cervical vertebræ, as to give them great mechanical power.

Next to these in force, the Scaleni may probably be classed; especially the anterior and middle Scaleni. The Recti capitis interni majores perhaps follow the Scaleni in power, as they are considerable muscles, and have by their insertion into the cuneiform process of the os occipitis, a more efficient action on the head, than most of the following. The Longi colli, though muscles of some strength, take their origins, and are inserted so near to the centres of motion of the cervical vertebræ, that they cannot possess much in-

fluence in this movement of the neck. The Sterno-hyoidei and Sterno-thyroidei, muscles arising from the sternum, have considerable mechanical advantage; but they cannot have much effect in the flexion of the neck, inasmuch as they are slender muscles, and as the os hyoides, and thyroid cartilage, into which they are inserted, are with difficulty rendered sufficiently firm for any length of time. The Recti capitis interni minores are very small muscles. These are all the flexors of any note. The extensors are much more numerous, and some of them more powerful than any of the flexors.

Of the Extensors of the head and neck, the Complexi, and Splenii capitis have, I conceive, most power. They are large muscles, have extensive origin and insertion, and much mechanical advantage, from the distance of their insertions from the centres of motion of the vertebræ. The Trapezii, and Levatores scapularum, when the scapulæ are fixed, may be ranked next in power; the former would perhaps be superior to any, were

their action not oblique. The Trachelo-mastoidei, from their insertion into the mastoid process; and the Splenii and Semispinales colli, from their numerous points of origin and insertion, are also powerful extensors. For the same reason, the Interspinales colli, and that part of the Multifidus Spinæ belonging to the neck, follow these last. The Recti capitis postici majores, arising from the projecting spine of the dentata, and being inserted into the transverse ridge of the occiput, are strong muscles, and possessed of much mechanical power. The Cervicales descendentes, the Transversales, and Intertransversales colli, muscles not readily separated from each other, are also extensors. Last in effect are the Recti capitis postici minores, and Obliqui capitis superiores.

A careful review of all the opponent muscles of the head and neck, must, I think, convince every impartial inquirer, of the superior power of the extensors of this part of the vertebral column, to that of the flexors.

In examining the remainder of the vertebral column, it will be most expedient to treat of the moving powers of the back and loins together; for most of the muscles, which act on the former, induce similar motions in the latter.

It may at first be thought, that the attempt to compare the flexors of the dorsal and lumbar vertebræ with the extensors, must be involved in difficulty. from the intricacy of the former, both as to their situation and action. Much of this difficulty, will be removed by reflecting, that it would be improper to include as flexors of the spine, both the abdominal muscles, and also the muscles which surround the chest, and act on the ribs; for the former, being inserted into the lower ribs, plainly act on the latter. In a *mechanical* point of view, therefore, they should be considered as merely a continuation of the latter.

Of the flexors. From the extensive origin and insertion of the external and internal oblique muscles, and from the greater part of their attach-

ments being very far anterior to the vertebral column, they must be powerful flexors of the spine. The obliquity of their course, however, though it increases their latitude of motion, yet certainly lessens their power. The Recti muscles, although generally thin, are of considerable breadth; and from their insertion into the ensiform cartilage, and into the cartilages of the ribs on each side, which are most anterior to the vertebral column, they act upon arms of levers, which endow them with the greatest mechanical advantage. The Transversales Abdominis running nearly horizontally, are not flexors of the spine. The Psoæ muscles are by many classed as flexors; but when it is remembered, that the bodies of the lumbar vertebræ project very much forward, and that these muscles are placed at their sides, it will I think, appear, that their chief use is to govern the lateral motions of the spine.*

Of the extensors. The Longissimi dorsi and

* The action of the Psoas magnus on the *thigh* has been treated of elsewhere.

Sacro-lumbales are extensors possessed of great force in every respect. This is proved by the following facts. 1. The very numerous points of origin, and insertion of their fibres. 2. Their points of origin and insertion, being, most of them, far behind the centres of motion of the vertebræ, namely, into the posterior projecting surface of the sacrum, and those of the Sacro-lumbales also, into the angles of the ribs, which are very far behind the bodies of the vertebræ. 3. The thickness a tendon would be of, if formed by the aggregate of the tendons of the Sacro-lumbales alone, would prove the strength of the muscle acting upon it, for the thickness of a tendon is always proportional to the strength of the muscle to which it belongs.

The Latissimi dorsi are also extensors of great strength. They have very extensive origins, and considerable mechanical power, when the arm is fixed. The following fact is perhaps a proof of their influence in extending the spine.—When the arms are supporting a considerable weight, being at

the same time, either stretched forth, or raised above the head; great weakness is often felt in the back and loins, much greater than the same weight placed on the back would produce. Does not the cause of this weakness arise from the extensors of the spine lacking the assistance of these muscles? for did they act, they must greatly tend to draw down the arms, which have to support the weight. The Quadrati lumborum follow these, and are powerful muscles. The Spinales, and Semispinales dorsi, part of the Trapezii, the Multifidus Spinæ, and the Interspinales, and Intertransversales dorsi et lumborum, are the remaining extensors of the spine. It is no way necessary to treat of these muscles singly, as they correspond to those of the neck, and what has been observed respecting their action there, is also applicable here.

With respect to the comparative forces of the muscles of the back and loins, it appears to me, we are brought to the same conclusion as in the neck;—that the extensors are more powerful than

the flexors; and this, not only from a view of their anatomy, but also from the following consideration. When the body is erect, as the flexors of the spine (the abdominal muscles,) have to support much of the weight of the abdominal viscera, and also indirectly of those of the thorax, by supporting the Diaphragm, they plainly act on the ribs with great force, which force must tend to bend the spine forwards. This effect can only be prevented by the action of the muscles behind the spine; and the force they would have to exert, would just equal that of the flexors, if a line falling perpendicularly through the centre of gravity, when the body is erect, passed through the centres of motion of all the vertebræ. But this is far from being the case. The line mentioned would pass in front of all the vertebræ of the back.

This fact shows, that the greater part of the whole weight is placed in front of the centres of motion, or in other words favouring the flexors. Therefore, the extensors have not only to exert a force sufficient to counteract that of the flexors,

but, in addition to this, they have to support a weight, which is favouring the flexors; and must therefore be more powerful than the flexors.

THE motions of the lower jaw, and of the shoulder, no way corresponding in the human body to those of most joints, it would appear, that the terms extension and flexion, are not exactly applicable to any motions of these joints; and, therefore, that they do not come within the limits of this inquiry. That motion of the shoulder, which is by some called extension, is more properly abduction of the arm, and is analagous to the abduction of the thigh.

OF JOINTS, THE FLEXORS OF WHICH ARE MORE POWERFUL THAN THE EXTENSORS.

There are, on the other hand, some joints, of which the flexors are undoubtedly the more powerful muscles. These are the joints of the fingers and toes; for they have about double the number

of muscles acting as flexors, that they have as extensors.

The muscles of the thumb may apparently differ from those of the fingers in their relative power; for the thumb has three extensors, and only the same number of muscles *nominally* flexors. But it must be remembered, that the long flexor of the thumb is a very powerful muscle, much more so than any of the extensors singly; and, that the adductor, and abductor pollicis, when acting together, must in a considerable degree aid the flexors.

The flexors of the elbow are probably, in most persons, the more powerful muscles. Although the Triceps extensor cubiti, may be a muscle perhaps equal in power to the Biceps and Brachialis internus together, yet, when it is considered, how many of the muscles of the forearm take their origin from the condyles of the humerus, and that all these act as flexors, there can hardly remain a doubt, that the flexors of this joint, are more powerful than the extensors.

The mechanism of the wrist, differing from that of most joints, it is scarcely correct to consider the muscles which move it backwards or forwards, as either solely extensors or flexors.

Since it moves nearly in an equal degree both ways; when the hand is in an extreme position backwards, the muscles which bring it forwards, first act as extensors, and then as flexors; and *vice versa,* when the hand is bent forwards, the muscles which carry it back, must first act as extensors, and then as flexors. It has, however, been the custom of anatomists to call those muscles, which carry the hand back, the extensors, and those which bring it forwards, the flexors of the wrist. Of the two sets of opponent muscles of the wrist, it is difficult to decide, from any anatomical difference, which are the most powerful; for although the whole of those muscles, which, by their contraction, tend either directly or indirectly to produce that position of the hand, which anatomists have denominated flexion, are inferior in *number* to those, which have a ten-

dency to induce, that named extension; yet, taken individually, most of the former have a superiority over the latter, sufficient at least to make up for the difference of number; perhaps, even to render their united power greater, than that of the extensors.

OF the joints which have now been treated of, the knees, ancles, hip, neck, back, and loins, deviate in a remarkable degree from the doctrine, laid down by Richerand, that the extensors are in general *weaker* than the flexors. Now these joints form by far the majority of the most important joints. But if the comparative power of the opponent muscles, of a great majority of the principal joints, tends to prove the contrary of the proposition advanced by Richerand, it must follow, that the doctrine cannot be admitted; and even that the contrary is the case; i. e. That the extensors are in general *more powerful,* than the flexors.

Again, could it even be proved, that the mechanism of the muscles, and joints, is apparently

in favour of the doctrine, how could the following *facts* be explained upon the supposition of it?

First. If we suppose a man placed between two heavy bodies, which he wishes to put into motion; and that his back is bound against one, and his feet against the other, can there be any doubt in what manner he would attempt to move them? He would certainly, by extending his back and limbs try to thrust them apart. He would not even attempt to bend his joints, and thus endeavour to draw them together. The power he could exert in the former case, would be almost irresistible, when compared with that in the latter. This experiment would shew that the extensors of the back, thighs, legs, and ancles are far more powerful than the flexors.

Secondly. Every one must be aware, how exhausting is the labour of walking any distance over heavy land. This undoubtedly arises from the comparative weakness of the flexor muscles of the lower extremities. In proof of it, I may mention, that many opportunities have occurred

to me, of noticing, that a person is more fatigued by traversing ploughed land for the short space of one mile, than by walking along roads for many times that distance. This shews, that the flexors of the knee and thigh suffer much more from having to raise their respective limbs, and the earth adhering to the feet, than the extensors of these joints, from having to support the whole body (a far greater weight) for a longer time.

Thirdly. In the disease named tetanus, as soon as it becomes general, opisthotonos almost invariably occurs. The whole of the spine is bent back, and the thighs, legs, and ancles are rigidly extended. The explanation of this must depend on one of the following suppositions. Either, that in this disease the extensors are almost always in a state of spasm, while the flexors are not; or, that both sets of muscles are equally affected, but that the extreme state of extension of most joints arises from the superior power of their extensors, when all the muscles are exerted to the uttermost. The former of these supposi-

tions cannot be admitted; for we have no reason to believe, that either set of muscles is more affected than the other. Before tetanus proves fatal, the flexors are evidently affected equally with the extensors. The latter then must be the case; for if the flexors of these joints were the most powerful, the limbs of a patient in complete tetanus, would assume the position of those of the fœtus in utero. He would lie with his head and spine bent forwards, with his knees touching his chin, and his heels his buttock; a position, which, I believe, a patient in complete tetanus never assumes.

Fourthly. The following experiment will prove, that the effective power of the extensors of the vertebral column is greater than that of the flexors.—If an active person be placed supine on two chairs, which are at such a distance from each other, that only the back of his head rests upon one, and his heels upon the other, he will be able to support the whole weight of the body in a straight line, without any intervening prop,

for some time. This is of course effected by the action of the extensors of the neck, back, loins, and thighs. But if the subject of the experiment be placed in a prone position, with his insteps on one chair, and his cheek upon the other, he will not be able to support himself, even for an instant; and will perceive, that the impotence arises from his not being able to bend his spine forwards, and thus support his body. In this last case, the flexors of the vertebræ attempt to effect, what the extensors were able to perform in the former, but fall far short of it.

Lastly. Were there no experiments in proof of these arguments, the consideration of this fact must be decisive.—That, when a man is erect, standing,* or walking, the gravitation of the superincumbent parts tends to bend the joints of the neck, back, perhaps of the loins, of the hips, knees, and ancles;—that this force is operating

* By standing, is not here meant that extreme state of extension of the joints of the lower extremity, when a person is resting on one leg, and trusting to the ligaments of the knee, the body being at the same time nicely balanced on the pelvis; which position is aptly termed in military tactics—*standing at ease.*

in favour of the flexors, and against the extensors. The extensors of all these joints, therefore, must be more powerful than the flexors; for they are habituated to a far greater exertion, which, it is an established law in physiology, increases the power of muscles in proportion.

Richerand, in concluding this subject, enters into an explanation of some phenomena connected with sickness, and old age, and endeavours to prove them, conformable to the doctrine he has laid down. The following are his words:—

"Towards the middle of life the preponderance of the flexors over the extensors becomes less apparent; a man enjoys fully and completely his power of locomotion; but as he advances in years, this power forsakes him; the extensor muscles gradually return to the state of comparative debility of infancy, and become incapable of supporting the body in a fixed and permanent manner." And again "Disease and excesses of all kinds occasion in the extensor mus-

cles a relative weakness that is very remarkable; hence we see convalescents, and those, who have been addicted to voluptuousness, walk with bending knees; the more so as their debility is greater, and as the force of the extensors is more completely exhausted."

When we reflect on their physiology and functions—when we remember, that opponent muscles are nourished from the same source, and frequently supplied with energy from the same nerves, we cannot believe, that from any cause acting on the body generally, one set of muscles suffers in a greater degree than the other. Voluptuousness, and the decline of life, must affect the whole body, and therefore the flexors as well as the extensors. Why then should a cause, acting on both sets of muscles equally, induce in the latter, a greater degree of weakness than in the former? All the muscles must suffer in proportion to their former strength.

Again; the doctrine does not accord with an

established law in physiology—that nature invariably supports, as far as possible, those parts, which most require support. Of this we have proof in the admirable manner, in which bones, bent from disease or some other cause, are often defended from any further distortion, by a greatly increased deposition on their concave side, which necessarily requires most strength. And for the same reason, if either set of muscles, the flexors of the lower extremities should suffer, rather than the extensors; for the latter have the whole weight of the body to support.

If the yielding of the extensors arises from their having lost strength in a greater ratio, than the flexors; a great weight placed on the shoulders of the healthiest man would produce a *magical* effect, for any man will walk with bending joints under a load sufficiently heavy. Can it be supposed that the weight has the power of actually weakening the extensors?

Due reflection will at once enable us to per-

ceive the true cause of the bending of the joints, whether under a heavy load, or from old age, or sickness. When a weight is placed on any one's shoulders, the extensors as well as the flexors, are just as powerful as before; but the weight, which the extensors have to support, being so much increased, they must of necessity in some degree yield to it. In a similar manner, in sickness and old age, the *weight* of the body operates; and it is a manifest omission on the part of Richerand, that he has not taken this into consideration. Under either of these last mentioned circumstances, all the muscles lose strength in an equal degree, while the body remains of nearly the same weight as formerly; at least it does not lose weight in a ratio at all equal to that of the loss of strength; and therefore, the extensors, being unable to support the present weight with the same facility, with which they did the former weight, must yield to it precisely in the same manner, as the extensors of the person in health, when loaded with an extraordinary weight.

The following question may possibly present itself on this explanation: from what cause does it arise, that when the extensors have yielded to the superincumbent weight, whether an additional one, or that of the body, that the joints do not entirely give way, but the person is still able to support the weight, though staggering under it?

Richerand offers the following explanation:— "The flexion of the knees is then limited by that condition, in which the tendons of the extensors of the leg act on the tibia, at an angle sufficiently great to make up for their diminished energy."

This is fallacious reasoning, and can contribute, nothing to the intended purpose.

The sophism, or deception consists in this, viz. that it makes a reference to a condition, which does not exist, and the supposition of which, is contradictory to the general proposition in mechanics, relative to the lever.

Let A B C, be the thigh; C E D, the leg;

C, the centre of motion of the joint; K, the patella. And let the joint be somewhat bent, as in figure I. Richerand supposes, that there is a condition, in which the extensors act on the tibia, at such an angle, (an angle sufficiently great, is his expression) as makes up for their diminished energy; and he affirms, that the flexion of the knee is limited by this condition.

Now let A P, be the perpendicular line passing through the centre of gravity of the whole body, and of course, through the centre of pressure (P,) of that foot, upon which the body is resting at the time. Let A, be any point of this line, taken, in that part of it which passes through the head of the femur. Draw the straight lines, A C, C P, and draw C F, perpendicular to A P. Draw the straight line K G, reaching from the centre of the patella to the head of the tibia; and draw CH, perpendicular to K G. Join K C, C G.

Here it is evident, that the femur is a crooked lever, truly represented by the mathematical lines

A C, C K;—that the power in this lever is the weight of the body acting in the direction A F P, and that the resistance is the re-action of the patella and its ligament against the extensor muscles, in the direction K G. Again the tibia, with the foot, forms a crooked lever P C, C G; of which the power is the re-action of the ground at P, against the weight of the body; and the resistance is the action of the extensor muscles, upon the patella, and its ligament, in the direction of G K.

Now by the general proposition of the lever, the effect of the power (weight of the body) in bending the joint, is to be measured by the length of the line C F, and the greatness of the power, conjointly. In like manner the effect of the muscles, which are the resistance to this, is to be measured by the line C H, and the force of these muscles conjointly. But C F, grows greater, and greater as the joint bends, (Fig II.) and C H does not grow greater, but rather less; and the force of gravity is not altered. If then the force of the

muscles were not altered, and the flexion were to depend for its limit, merely upon the bending of the joint, it would be so far from having any limit, from that cause, that the force of gravity would act upon the joint continually more, and more, till it brought the body to the ground. It is plain therefore that, to prevent this effect, the strength of the muscles must be increased ; and this will necessarily happen from a property of muscle and elastic bodies in general, which has been laid down in my fifth principle, " that a muscle has more power of contraction, when stretched than when shortened." This evidently is the reason, why the extensors can support a greater weight, when the knees are somewhat bent; for then these muscles are so far stretched, and hence their power of contraction so far increased, that it just balances the opposing weight, though acting by a more favourable lever than before.

I flatter myself that I have now made it evident, that the flexor muscles cannot with justice be considered as more powerful than the extensors; but, on the contrary, that in far the more numerous, and most important cases, the extensors are the more powerful of the two.

My reason for bringing forward the substance of my investigation, arose from the following persuasions: viz. that it is of importance to the surgeon, not only to have knowledge of the most proper position for an injured limb, but also clearly to understand, why he makes choice of such position;—that this can only be acquired by knowing the comparative *lengths* as well as *forces* of the opponent muscles;—and that, whereas Richerand appears to have given an incorrect explanation of the subject, his doctine must, if prevalent, have a tendency to produce errors in that important branch of practice.

FINIS.

ERRATA.

Page 21, line 11, for *Peronneus* read *Peroneus.*
.... 38, ... 8, for *hip* read *hips.*